A NAVAL POSTGRADUATE DENTAL SCHOOL ANALYSIS OF INITIAL ENDODONTIC TREATMENT

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CERTIFICATE OF APPROVAL

MASTER'S THESIS

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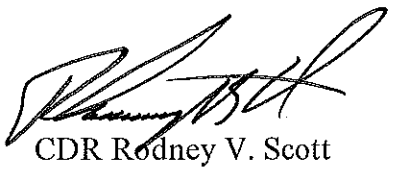

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Abstract

Introduction: Initial non-surgical endodontic treatment is associated with high healing rates and clinical success (functional). The endodontic literature contains numerous longitudinal studies examining outcomes of initial endodontic treatment. Several variables have been identified as potential contributors to healing. **Objective:** This retrospective observational study evaluated the outcome of initial endodontic treatment performed by Navy Endodontists or graduate endodontic residents at the Naval Postgraduate Dental School and identified variables that affect these outcomes. **Methods:** Clinical and radiographic data were obtained from initial endodontic treatment of 204 subjects. A one year follow-up examination was performed. The healing rate was determined from radiographic scoring by three board certified endodontists. Pre-operative, inter-operative, and post-operative examination data were analyzed using Fisher's Exact Chi-squared, logistic regression and odds ratios to evaluate the influence of multiple variables on healing outcomes. **Results:** Sixteeen of the 204 subjects were excluded due to missing data; the final cohort of 188 subjects consisted of 66% males, 34% females with a median age of 48. The median follow-up time was 14.5 months. The overall healing rate was 71.9%, defined by the absence of a radiographic lesion and no clinical signs and symptoms of disease. The functional rate was 95.2%, defined by the absence of clinical signs and symptoms. Logistic regression analysis indicated a negative effect on healing for those subjects presenting with: a pre-operative diagnosis of pulp necrosis, periapical radiolucency, procedural complications, treatment requiring more than 1 appointment or smokers. **Conclusion:** Preliminary evaluation indicated a healing rate of 71.9% with a functional rate of 95.2%. The presence of a necrotic pulp, periapical

radiolucency, procedural complication, treatment requiring more than 1 appointment or smoking significantly decreased healing outcomes.

Key Words
Outcome assessment, initial endodontic treatment, non-surgical root canal treatment, outcome of endodontic treatment, periapical healing, periapical index, PAI

Introduction

Endodontic literature varies in its report of treatment outcomes, and the parameters used to define "success". The use of the terms "success" and "failure" in describing endodontic treatment outcomes dates back to a 1956 text by Lars Strindberg titled, "*The Dependence of the Results of Pulp Therapy on Certain Factors; an Analytic Study Based on Radiographic and Clinical Follow-up Examinations*". This terminology continues to remain in widespread use today. Its main limitation is its' focus on the treatment aspect and less on the patient or actual disease process. Defining the results of endodontic treatment as either "success" or "failure" does not fully account for the numerous factors influencing outcomes; many of which are beyond the practitioner's control. In 2011, Wu proposed the terms "effective" and "ineffective" to discuss endodontic outcomes judged after one year. The additional category of "uncertain" was applied to cases that were asymptomatic but did not demonstrate a change in radiographic lesion size. Teeth in this category would require further monitoring. Here, the emphasis falls on the effect of treatment provided by the practitioner and largely discounts the patient's role on the outcome.

A description that better accounts for the roles of both treatment and the patient was published in 2004. Friedman and Mor introduced the terms "healed" and "healing". They argued, the goal of endodontic therapy is to prevent or heal disease, i.e. apical periodontitis. Accordingly, endodontic treatment outcomes can better be defined in reference to healing and disease as follows:

1. Healed: both the clinical and radiographic presentations are normal
2. Healing: because healing is a dynamic process, reduced radiolucency combined with normal clinical presentation can be interpreted as healing in progress
3. Disease: radiolucency has emerged or persisted without change, even when the clinical presentation is normal, or clinical signs or symptoms are present, even if the radiographic presentation is normal

This more physiologically accurate description of healing following endodontic treatment is not limited to a dichotomous outcome of either "success" or "failure".

The goals a clinician may set for the outcome of treatment may differ greatly from those of the patient along the healing continuum. A patient's priorities could range from healing to prevention of disease or perhaps simply maintaining functionality. In the latter case, the term "functional retention" or "functional" may be most appropriate: the tooth is clinically normal with an undetermined radiographic status. What cannot be disputed however are the results of large epidemiologic studies routinely demonstrating retention rates from 94% to 97% for root canal treated teeth (31,25).

Brynolf (40) noted only 7% of anterior root canal treated teeth demonstrate the absence of inflammatory cells in the periapical tissues. Endodontic therapy has been compared to a chain whose strength is only as great as its weakest link. Effective cleaning, shaping, and obturation of the root canal are all essential links of this chain. In order to predictably achieve success in endodontic therapy, Schilder (2) stated, the root canal system must be cleaned of organic remnants and shaped to receive a three-dimensional hermetic filling of the entire root canal space. (Is this a direct quote?)

The ability to consistently achieve success in endodontics is complicated by many variables. A patient's medical condition profoundly affects success. In 2003, Fouad and Burleson (13) determined that diabetic patients had a significantly reduced healing compared to non-diabetics in cases with pre-operative perirapical lesions. Diabetes mellitus and coronary artery disease were significant risk factors contributing to tooth extraction following non-surgical root canal treatment (NSRCT) at 2 years in a retrospective study examining nearly 50,000 teeth (37). In 2006, Caplan et al. (22) showed a relationship between incidence and duration of lesions of endodontic origin and coronary heart disease (CHD) in men <40 years old. In 2009, Caplan et al. (30) found a correlation between self-reported history of endodontic treatment and the prevalence of CHD. In a 2006 survey, Joshipura et al. (23) noted a relative risk for CHD of 1.21 in men with more than one root canal treated tooth compared to those without endodontically treated teeth. A review of the literature by Duncan and Pitt Ford (19) discussed the lack of evidence of smoking on the incidence or healing of periapical periodontitis.

Pre-existing tooth conditions also impact the outcome of initial endodontic treatment. Field et al. (8) found treatment of anterior teeth more successful than posterior teeth. In another retrospective study, Orstavik et al. (9) determined that tooth type had a significant effect on outcome. Pre-operative symptoms and the intra-operative pulpal and periapical status of teeth have been associated with treatment outcome in both retrospective and prospective studies (10-15). In 2004, a meta-analysis by Kojima et al. (18) reported a significantly better success rate when treating vital pulp versus non-vital pulp cases. Root canals with tight isthmuses and other anatomic irregularities provide a haven for microbes. These microbes and their by-products challenge treatment effectiveness (3-5). The presence of an apical radiolucency was found to be prognostic of decreased healing or survival following RCT (35,36). For molars, pre-operative periodontal condition correlated with negative outcome of root canal treatment (RCT) at 4 years or more (32).

Intra-operative variables have also been shown to affect treatment outcome. Procedural complications such as perforation, over-instrumentation, and length of obturation have been cited as negatively affecting the outcome (9, 11, 12). Oliet (6) determined that overextension of obturation materials significantly decreased healing. A study by Smith et al. (7) reported a significantly higher healed rate in teeth with a flush obturation vs. over and under extended obturation. Fractured instruments, however, do not result in a significant decrease in healing (16,17,34).

A systematic review of post-operative variables published in 2010 by Ng, Mann and Gulabivala (33) reported a crown restoration following treatment, the presence of both mesial and distal proximal contacts, a tooth not functioning as an abutment for a removal or fixed prosthesis, and tooth type (non-molar tooth) significantly improved tooth survival following NSRCT.

Clearly, the determination of appropriate treatment techniques and materials depends upon recognizing and understanding the influence of these predisposing factors. Currently, no studies have been performed to assess the outcome of initial NSRCT in a U.S. Navy patient population. The purpose of this retrospective observational study was to evaluate the outcomes of initial endodontic treatment performed by Naval Postgraduate Dental School

(NPDS) endodontic residents and Navy endodontists and to identify variables affecting these outcomes.

Materials and Methods

This study was approved by the Walter Reed National Military Medical Center (WRNMMC) Institutional Review Board. Subjects were consented from a pool of patients previously treated by residents in the NPDS Endodontic Clinic. Additionally, patients treated by Navy Endodontists at other clinics were included if they met study inclusion criteria based on a review of their dental treatment record. Specific inclusion criteria included; initial NSRCT exclusively performed by an NPDS endodontic resident or Navy endodontist at least 12 months prior to follow-up evaluation with at least one final obturation radiograph available for review. All subjects were at least 18 years old. Exclusion criteria included; NSRCT retreatment, surgical root canal treatment (SRCT), or canal obturation materials other than gutta percha.

Clinical Procedures A power analysis was performed based on previous findings that 85% of subjects would heal following NSRCT (15,25,27,28) and a 3.0% tolerable margin of error. Assuming a 10% dropout rate, a sample size of 600 was required. The analysis of this cohort included the collection of existing pre-operative and intra-operative data, including radiographs, from the patient record. Follow-up data from clinical and radiographic examinations were performed by the study investigators. (Table 1).

Table 1. Data points (preoperative, intraoperative, and follow-up) collected from patient records and examinations.

Preoperative
Age
Tooth #
Tooth type
Medical conditions
- Hypertension
- Smoker
- Diabetes Type:____
- Coronary heart disease

Symptoms
Pain (0-10)
Can locate pain by quadrant
Can locate pain by tooth
Electric pulp tester EPT
Palpation
Sinus tract
Swelling
History (hx) of orthodontics
Hx of external resorption
Presence of intracanal post
Caries
Cold sensitivity
Percussion
Mobility
Bleeding on probing
History (hx) of bleaching
Hx of internal resorption
Open restorative margin
Restoration present
Duration of symptoms
Probing depths
Intact lamina dura
Radiolucency size
Preoperative pulpal diagnosis (dx)
Preoperative apical dx

Intraoperative
Electronic apex locator used
Patency achieved
Type of irrigants used
Calcium hydroxide use
Procedural complications
Use of intraorifice barrier
# of treatment sessions
Obturation fill length
Postoperative pulpal dx
Postoperative periapical dx
Date of treatment completion
Final treatment PAI score

Follow-up
Date of follow-up exam
Medical conditions
- Hypertension
- Smoker
- Diabetes Type:____
- Coronary heart disease

Symptoms
Pain (0-10)
Electric pulp tester EPT
Palpation
Sinus tract
Swelling
Time lapse to restoration
Duration of symptoms
Cold sensitivity
Percussion
Mobility
Periodontal screening
Bleeding on probing
Probing Depths
Intact lamina dura
Radiolucency size
Follow up apical diagnosis
Caries
Presence of coronal restoration
Presence of intracanal post
Open restorative margin
Follow-up PAI score

Each subject's dental record underwent a thorough review focusing on information collected during the initial treatment, a review of the patient's health history and their intervening dental history. Diagnostic copies of the initial post treatment radiographs were identified from the records or on a network radiographic archive (X-ray Vision). Study investigators conducted standardized 12-month follow-up examinations. This comprehensive extraoral and intraoral diagnostic evaluation consisted of; assessment of palpation, percussion, cold and EPT responses, periodontal health, degree of tooth mobility, and the restoration status of the tooth. (Table 1). Based upon radiographs, the examining clinician made a determination of the post treatment and follow-up obturation length defined as:

1. Flush: within 2 mm of the radiographic apex
2. Overextended: excess beyond the radiographic apex
3. Under-extended: greater than 2 mm short of the radiographic apex

All information was recorded on standardized pre-operative, intra-operative, and post-operative data collection forms. Patient identifiers were archived separately from the data collection forms. All data were referred to by a de-identified subject number only.

All radiographs were captured the aid of an XCP paralleling device (Rinn Dentsply, York, PA). Digital radiographs for immediate post-treatment and follow-up were exposed with Kodak RVG 6100 sensors (Carestream Dental LLC, Atlanta, GA) or Schick sensors (Schick Technologies Inc, Long Island City, NY) and transferred for archive via recordable compact disc. Conventional radiographs utilizing Kodak Insight film (Carestream Dental LLC, Atlanta, GA) were developed in a Peri Pro III developer (Air Techniques Inc, Hicksville, NY) and subsequently scanned and digitized with an HP PhotoSmart S20 scanner (Hewlett-Packard Company, Palo Alto, CA).

Data Analysis The primary study outcome, healed versus not healed, was based on clinical and radiographic assessment. Patients free of clinical symptoms and without radiographic apical lesions were considered healed. Randomized PAI analysis—based on the system developed by Orstavik—of immediate post treatment and follow-up radiographs were performed by 3 blinded board certified endodontists (24). The coronal aspect of each tooth was masked to prevent reviewer bias. Radiographs were scored as follows: healed (scores of 1 or 2), unsure (a score of 3), and not healed (scores of 4 or 5).

SPSS v15.0 (SPSS Inc, Chicago, IL) was used to perform descriptive, chi-squared, odds ratio and logistic regression analyses. A total of 204 subjects were enrolled. It was discovered that pre- and peri-operative data were missing on 16 reducing this number to 188. Forty-nine subjects with radiographic PAI scores of 3 were excluded from the healing rate analysis bringing the final number of subjects to 139. Data collection will be completed when 600 subjects are enrolled.

Results

Subject demographics revealed that 34% (64 subjects) were female and 66% (124 subjects) were male. Their ages ranged from 21 to 87 years, with a median age of 48. The follow-up periods ranged from 12 months to 10.5 years; the median follow-up period was 14.5 months.

Statistical analysis revealed that, 71.9% (100 subjects) of the subjects were categorized as healed, meaning that the patient had a PAI score of 1 or 2 and were asymptomatic upon clinical evaluation. The non-healed group (PAI of 4 or 5, or symptomatic) comprised 28.1% (39 subjects). In a secondary analysis of all 188 subjects, 95.2% (179 subjects) were categorized as functional or asymptomatic based on the absence of any clinical symptoms at the follow-up clinical examination. The remaining 4.8% (9 subjects) of this group demonstrated clinical symptoms.

The odds ratio and Fischer's exact chi-squared revealed several variables influencing treatment outcome. There was a strong trend for subjects with pre-treatment diagnoses of vital pulp, 89.6% (69 of 77 subjects) to be radiographically healed at one year follow-up. Subjects with a pretreatment diagnosis of pulp necrosis had a 50% chance of being healed at the follow-up appointment. Subjects with a post-treatment radiographic lesion, and smokers were 8 to 9 times less likely to heal ($p<0.01$). Procedural complications ($p=0.02$) and treatment completed over multiple visits ($p=0.03$) indicated that a patient was 3.4 and 2.3 times less likely to heal respectively.

Discussion

In this analysis, the overall healing rate was 71.9%. There is a great degree of variability between the outcomes reported in endodontic literature. According to Friedman in a review of 50 studies from 1956 to 2002 (28) at the end of one year, 90% of teeth that will eventually heal demonstrate signs of healing. However, complete healing may take 4-5 years. In a 1995 study by Ray with a one year recall, the radiographic healing rate was 61% (41). A study by Ng with a two year recall reported had a healing rate of 83% (33) and a longer study by Molven (42) found that persistent asymptomatic lesions continued to heal up to 27 years after initial treatment.

A distinct advantage of retrospective studies is they allow long term follow-up of a large cohort. Another advantage of retrospective studies is they are often shielded from bias because the data used were collected for reasons other than the question being studied. Limitations of retrospective studies include the inability to randomize subjects or standardize treatment protocols, and inconsistencies in the amount or quality of data available (25). The present observational study applied aspects of both prospective and retrospective models by gathering historical as well as direct patient data.

Conclusion

Based on the results of this study, the overall healing rate was 71.9% with a clinical success rate of 95.2%. Variables that negatively affected outcome included: post-treatment radiographic lesions, smoking, a non-vital pretreatment diagnosis, procedural complications and multiple visits. Gender, age, and other health conditions (diabetes, heart disease or hypertension) were not significantly correlated with healing.

Placed in a larger context, this is the first study to analyze the outcomes of treatment completed by endodontic specialist in the US Navy. This study provides valuable insight into variables that affect treatment outcome for a previously un-examined patient and provider population. It is hoped that the results of this study will ultimately allow us to provide more accurate prognosis and improved treatment planning related to initial non-

surgical root canal treatment. Further outcomes studies on the results of non-surgical root canal retreatment, surgical root canal treatment, and recalls greater than 12 months on the same population are under consideration.

References

1. Schilder H. Cleaning and shaping the root canal. Dent Clin North Am 1974;18:269-96.

2. Cohen S, Hargreaves K. Pathways of the pulp. St. Louis: CV Mosby Co., 2006:290-348.

3. Skidmore AE, Bjorndal AM. Root canal morphology of the human mandibular first molar. Oral Surg Oral Med Oral Pathol 1971;32:778-84.

4. Vertucci FJ. Root canal anatomy of the human permanent teeth. Oral Surg Oral Med Oral Pathol 1984;58:589-99.

5. Yesilsoy C, Gordon W, Porras O, Hoch B. Observation of depth and incidence of the mesial groove between the mesiobuccal and mesiolingual orifices in mandibular molars. J Endod 2002;28:507-9.

6. Oliet S. Single-visit endodontics: a clinical study. J Endod 1983;9:147-52.

7. Smith CS, Setchell DJ, Harty FJ. Factors influencing the success of conventional root canal therapy-a five-year retrospective study. Int Endod J 1993;26:321-333.

8. Field JW, Gutmann JL, Solomon ES, Rakusin H. A clinical radiographic retrospective assessment of the success rate of single-visit root canal treatment. Int Endod J 2004;37:70-82.

9. Ørstavik D, Qvist V, Stoltze K. A multivariate analysis of the outcome of endodontic treatment. Eur J Oral Sci 2004;112:224-30.

10. Cotton TP, Schindler WG, Schwartz SA, Watson WR, Hargreaves KM. A retrospective study comparing clinical outcomes after obturation with resilon/epiphany or gutta-percha/kerr sealer. J Endod 2008;34:789-97.

11. Imura N, Pinheiro ET, Gomes BPFA, Zaia AA, Ferraz CCR, Souza-Filho FJ. The outcome of endodontic treatment: A retrospective study of 2000 cases performed by a specialist. J Endod 2007;33:1278-82.

12. Stoll R, Betke K, Stachniss V. The influence of different factors on the survival of root canal fillings: A 10-year retrospective study. J Endod 2005;31:783-90.

13. Fouad AF, Burleson J. The effect of diabetes mellitus on endodontic treatment outcome. J Am Dent Assoc 2003;134:43-51.

14. Hoskinson SE, Ng YL, Hoskinson AE, Moles DR, Gulabivala K. A retrospective comparison of outcome of root canal treatment using two different protocols. Oral Surg Oral Med Oral Pathol 2002;93:705-15.

15. de Chevigny C, Dao TT, Basrani BR, Marquis V, Farzaneh M, Abitbol S, Friedman S. Treatment outcome in endodontics: the Toronto study-phase 4: initial treatment 2008;34:258-63.

16. Crump MC, Natkin E. Relationship of broken root canal instruments to endodontic case prognosis: a clinical investigation. J Am Dent Assoc 1970;80:1341-7.

17. Spili P, Parashos P, Messer H. The impact of istrument fracture on outcome of endodontic treatment. J Endod 2005;31: 845-50.

18. Kojima K, Inamoto K, Nagamatsu K, Hara A, Nakata K, Morita I, Nakagaki H, Nakamura H. Success rate of endodontic treatment of teeth with vital and non-vital pulps. A meta-analysis. Oral Surg Oral Med Oral Pathol 2004;97:95-9.

19. Duncan HF, Pitt Ford TR.The potential association between smoking and endodontic disease. Int Endod J 2006;39:843-54.

20. Doyle SL, Hodges JS, Pesun IJ, Baisden MK, Bowles WR. Factors affecting outcomes for single-tooth implants and endodontic restorations. J Endod 2007;33:399-402.

21. Janket S, Baird AE, Chuang S, Jones JA. Meta-analysis of periodontal disease risk and risk of coronary heart disease and stroke. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2003;95:559-69.

22. Caplan DJ, Chasen JB, Krall EA, Cai J, Kang S, Garcia RI, Offenbacher S, Beck JD. Lesions of endodontic origin and risk of coronary heart disease. J Dent Res 2006;85:996-1000.

23. Joshipura KJ, Pitiphat W, Hung H, Willet WC, Colditz GA, Douglass CW. Pulpal inflammation and a incidence of coronary heart disease. J Endod 2006;32:99-103.

24. Ørstavik D, Kerekes K, Eriksen HM. The periapical index: a scoring system for radiographic assessment of apical periodontitis. Endod Dent Traumatol 1986;2:20-34.

25. Lazarski M, Walker W, Flores C, Schindler W, Hargreaves K. Epidemiological evaluation of the outcomes of nonsurgical root canal treatment in a large cohort of insured dental patients. J Endod 2001;27:791-6.

26. Holland R, Otoboni Filho JA, de Souza V, Nery MJ, Bernabe PEE, Dezan E Jr. A comparison of one versus two appointment endodontic therapy in dogs' teeth with apical periodontitis. J Endod 2003;29:121-4.

27. Penesis VA, Fitzgerald PI, Fayad MI, Wenckus CS, BeGole EA, Johnson BR. Outcome of One-visit and Two-visit Endodontic Treatment of Necrotic Teeth with Apical Periodontitis: A Randomized Controlled Trial with One-year Evaluation. J Endod 2008;34:251–7.

28. Friedman S. Prognosis of initial endodontic therapy. Endodontic Topics 2002;2:59-88.

29. Su Y, Wang C, Ling Y. Healing rate and post-obturation pain of single- versus multiple-visit endodontic treatment for infected root canals: A systematic review. J Endod 2011;37,125-32.

30. Caplan DJ, Pankow JS, Cai J, Offenbacher S, Beck JD. The relationship between self-reported history of endodontic therapy and coronary heart disease in the atherosclerosis risk in communities study. J Amer Dent Asso; 2009;140:1004-1012.

31. Salehrabi R, Rotstein I. Endodontic treatment outcomes in a large patient population in the USA: an epidemiological study. J Endod 2004;30:846-50.

32. Setzer FC, Boyer KR, Jeppson JR, Karabucak B, Kim S. Long-term prognosis of endodontically treated teeth: a retrospective analysis of preoperative factors in molars. J Endod 2011;37:21-5.

33. Ng Y, Mann V, Gulabivala K. Tooth survival following non-surgical root canal treatment: a systematic review of the literature. Int Endod J 2010;43:171-89.

34. Panitvisai P, Parunnit P, Sathorn C, Messer HH. Impact of a retained instrument on treatment outcome: a systematic review and meta-analysis. J Endod 2010;36:775-80.

35. Zhong Y, Garcia R, Kaye EK, Cai J, Kaufman JS, Trope M, Wilcosky T, Caplan DJ. Association of endodontic involvement with tooth loss in the veterans affairs dental longitudinal study. J Endod 2010;36:1943-9.

36. Santos SMC, Soares JA, Costa GM, Brito-Junior M, Moreira AN, de Magalhaes CS. Radiographic parameters of quality of root canal fillings and periapical status: a retrospective cohort study. J Endod 2010;36:1932-7.

37. Wang CH, Chueh LH, Chen SC, Feng YC, Hsiao CK, Chiang CP. Impact of diabetes mellitus, hypertension, and coronary artery disease on tooth extraction after nonsurgical endodontic treatment. J Endod 2011;70:1-5.

38. Liang YH, Li G, Wesselink PR, Wu MK. Endodontic outcome predictors identified with perapical radiographs and cone-beam computed tomography scans. J Endod 2011;37:326-31.

39. 2010 AAE-AAOMR Joint Position Statement. Use of cone-beam-computed tomography in endodontics.

40. Brynolf I. A histological and roentgenological study of the periapical region of human upper incisors. Odont Revy 1967;18,Suppl 11: 1-176.

41. Ray, Trope. Periapical status of endodontically treated teeth in relation to the technical quality of the root filling and the coronal restoration. Int Endod J, 1995.

42. Molven O, Halse A, Fristad I, MacDonald-Jankowski D. Periapical changes following root-canal treatment observed 20-27 years postoperatively. Int Endod J 2002;35:784-90.